Photo #

Project Galileo

or

"The little spacecraft that could"

Today, we're going to take a journey through time. Most of my talk will be about the recent discoveries made about Jupiter and its moons by the Galileo spacecraft, but we must start much earlier. Jupiter is unique in our solar system, because it emits more energy than it receives. It's like it's almost a star, but not quite. If things had worked out a little differently, we could be living in a solar system with two suns - that would certainly change the nature of everything on earth.

The earliest civilizations knew there were "regular" bodies in the night sky that didn't move with the rest of the stars. The ancient navigators certainly knew about the stars and planets. The Polynesians, ancient Greeks and Romans, the Mayans, all knew and used the night sky. In Europe, Portuguese sailors used the night sky for navigation, never venturing out of the sight of land, because they feared they'd fall off the earth. Christopher Columbus, of course, proved that the earth was round, with his voyage discovering the Americas in 1492.

- Stars around the poles (MB)
- A comet? (MB)
- Mayan observatory (MB)

Then, in about 1513, twenty-one years later, Copernicus determined that the earth was not the center of the universe - a very controversial theory at the time. [Pretty good looking fellow, and smart, too!] Goethe said, "Of all discoveries and opinions, none may have exerted a greater effect on the human spirit than the doctrine of Copernicus. The world had scarcely become known as round and complete in itself when it was asked to waive the tremendous privilege of being the center of the universe. Never, perhaps, was a greater demand made on mankind--for by this admission so many things vanished in mist and smoke! What became of our Eden, our world of innocence, piety and poetry; the testimony of the senses; the conviction of a poetic--religious faith? No wonder his contemporaries did not wish to let all this go and offered every possible resistance to a doctrine which in its converts authorized and demanded a freedom of view and greatness of thought so far unknown, indeed not even dreamed of."

- Photo of painting of Copernicus (Caltech archives)
- C's solar system diagram (Caltech archives)
- Solar system photo (PIA01341)

In fact, the earth and the other known planets of the time - Mercury, Venus, Mars, Jupiter, and Saturn - all revolve around the sun. Why did earlier

JPL photos of:
- Mercury

civilizations know about these planets? Because they could see them with their eyes in the night sky, as star-like objects that moved in a different pattern than the stars.

(PIA00437)
- Venus
(PIA00072)
- Earth
(PIA00122)
- Mars
(PIA02405)
- Jupiter
(PIA00235)
- Saturn
(PIA00400

But, the excitement was only beginning. European civilization was emerging from the Dark Ages and entering the Renaissance, an age of enlightenment. People had the luxury of being able to think and talk about things that couldn't be discussed before. Galileo made his telescope, and discovering that it made things far away appear to be closer and bigger, he turned it to the heavens and discovered that the earth isn't the only planet blessed with a moon. For this, he was excommunicated! He discovered four moons around Jupiter - little pinpoints of light that revolved around the planet! In his own words, "I should disclose and publish to the world the occasion of discovering and observing four Planets, never seen from the beginning of the world up to our own times, their positions, and the observations made during the last two months about their movements and their changes of magnitude; and I summon all astronomers to apply themselves to examine and determine their periodic times, which it has not been permitted me to achieve up to this day . . . On the 7th day of January in the present year, 1610, in the first hour of the following night, when I was viewing the constellations of the heavens through a telescope, the planet Jupiter presented itself to my view, and as I had prepared for myself a very excellent instrument, I noticed a circumstance which I had never been able to notice before, namely that three little stars, small but very bright, were near the planet; and although I believed them to belong to a number of the fixed stars, yet they made me somewhat wonder, because they seemed to be arranged exactly in a straight line, parallel to the ecliptic, and to be brighter than the rest of the stars, equal to them in magnitude . . .When on January 8th, led by some fatality, I turned again to look at the same part of the heavens, I found a very different state of things, for there were three little stars all west of Jupiter, and nearer together than on the previous night."

- Photo of painting of Galileo (Caltech archives)
- Photo of ground-based picture of Jupiter with 4 satellites (?)

- Photo of Galileo's drawing (Caltech archives)

"I therefore concluded, and decided unhesitatingly, that there are three stars in the heavens moving about Jupiter, as Venus and Mercury around the Sun; which was at length established as clear as daylight by numerous other subsequent observations. These observations also established that there are not

only three, but four, erratic sidereal bodies performing their revolutions around Jupiter."

I can imagine how excited Galileo was. He was seeing something that nobody else had seen. Even today, I find it thrilling to look at Jupiter through a pair of good binoculars and see those little pinpoints of light. On a dark night, they're very easy to see. [even in light-polluted, sometimes smoggy Pasadena]

Now we need to fast-forward to the twentieth century, when NASA started exploring the solar system. In 1977, two Voyager spacecraft were launched on a mission to investigate Jupiter and Saturn, with the possibility of continuing to Uranus and Neptune. We had received data from the earlier Pioneer spacecraft, and excitement mounted as the Voyager science teams decided the best strategy for taking data. My first job out of college was analyzing 102 trajectories and determining which would provide the best flight path for to obtain good images at Jupiter and Saturn. [Atlantic Ocean special] Finally, we were going to get close-up pictures of the Galilean satellites and some of Jupiter's other known moons. For a brand-new college graduate from the boondocks (me), it was really exciting to help plan that mission, even though some of the scientific theories seemed a bit far-out - a ring around Jupiter? oceans on Europa? Impossible, I thought.

Voyager launch picture (PIA01480)

Well, the Voyager data was exciting. For me, two of the discoveries were noteworthy, because I helped figure out how to take the pictures. We did discover a ring around Jupiter. [P.E.O. record keeping] But something even more exciting was about to be discovered.

Voyager Jupiter ring (PIA01529)

We had taken a lot of pictures of Io, and it looked a little like an intergalactic pizza that had traveled too far. One day, a spacecraft navigator named Linda was trying to fit a circle to the shape of the moon Io, the innermost Galilean satellite. Yes, we navigate spacecraft using the stars - it's just a little more sophisticated than the ancient mariners. She was using a computer [in 1979, the computer probably wasn't as powerful as your home computer] and the computer couldn't put a circle around a moon that we <u>knew</u> was round. Frustrated, she went to the photo library and pulled out a print of the picture. Io was still round, but it had a "bump" on the horizon - the plume from a volcano was rising from the horizon! Not only isn't the earth the center of the universe, but we aren't unique! Another body in our solar system has active volcanoes!

Voyager Io picture (PIA01530)

Voyage picture with volcanic plume (PIA01971)

About this time, we were beginning to think about the next mission to Jupiter - it would be an orbiter that would drop a probe into Jupiter's atmosphere

Galileo launch (PIA00726,

really incredible, when put in earthly terms. The radio transmitter on the spacecraft isn't any more powerful than the light bulb in your refrigerator. Try seeing it from a distance of about 500 million miles!

Finally, in 1995, we arrived at Jupiter. The mission at Jupiter was supposed to last two years, but we've been going for nearly five and have been extended again to continue our exploration. Jupiter itself probably has a solid core, surrounded by a deep ocean of liquid metalic hydrogen. On top of that is a thick layer of hydrogen and helium, which gradually changes from liquid to gas at higher altitudes. The upper most part of the atmosphere has huge storms. The Great Red Spot is one of these storms that has persisted for more than 300 years.

- Photo of Jupiter (?)
- Cutaway of Jupiter's atmosphere (P-48578)
- Great Red Spot (PIA00708)

Jupiter's rings are made of dust that has been blasted off the surface of four tiny inner moons named Metis, Adrastea, Amalthea, and Thebe. The man Galileo did not see these moons with his telescope.

- Ring drawing (PIA01627)
- Photo of the four inner moons (PIA01076)
- Ring picture (PIA00538)

The four Galilean satellites are named Io, Europa, Ganymede, and Callisto, starting from Jupiter and working out. However, I'm not going to talk about them in that order. Instead, Callisto will be first..

- Galilean satellites (PIA01400)

Callisto is the third largest moon in the solar system and is the most-heavily cratered object. Its surface is about 4 billion years old, which makes it the oldest landscape in the solar system. It shows almost no geologic activity on the surface. However, recent data indicates that it may have an ocean under its dark, icy surface. When a meteor hits it, the crust is broken and water flows out, creating bright rays and rings around the crater. The satellite has a thin carbon dioxide atmosphere. It is the darkest of all the Galilean satellites, but still twice as bright as our moon.

- Callisto pictures (PIA01657, PIA01648, PIA01649)

Ganymede is the largest moon in the solar system and larger than two planets, Mercury and Pluto. It, too, has an icy crust and a thin oxygen atmosphere. It exhibits signs of intense geologic processes. It has mountains and valleys, craters and lava flows, along with another terrain - grooves of ridges and troughs.

- Ganymede pictures (PIA00716, PIA01615)

and make multiple flybys of the Galilean satellites. In 1989, 379 years after Galileo the man discovered the Galilean satellites, Galileo the spacecraft was launched on board the space shuttle Atlantis. For launch safety considerations, the spacecraft was not launched directly to Jupiter, but needed to loop by Venus once and the earth twice to pick up enough energy to get to Jupiter.

PIA00727)

Launches are exciting! And, with a working spacecraft the anticipation of receiving data is great. All was going well for Galileo as we looped by Venus and the earth the first time. After that first swing by the earth, the project scientist, Dr. Torrence Johnson, postulated what alien beings would have learned about the earth from this flyby. They would have learned that our oceans are not very deep, compared to the size of the earth; that we have a magnetic field (why your compasses work) and probably a molten core. There would be indications of life, like a high amount of oxygen in the atmosphere and the detection of non-naturally-occurring radio signals, but no direct confirmation of life. Planet earth certainly would be a candidate for further exploration, based on this information.

- Galileo at Venus (PIA00221)
- Galileo at Earth-1 (PIA00076)

Catastrophe struck in April 1991. The high gain antenna failed to open. It was to be the primary method of communicating with earth and could support much more data than the low-gain antenna. It was supposed to open like an umbrella but at least two of its spokes were caught. It wouldn't work, ever, and we couldn't go fix it. One of the reasons that working at JPL is thrilling, is that many of the engineers thrive on achieving the impossible - they won't take "no" for an answer. Through clever data processing on the spacecraft and on the ground, we have been able to achieve over 70% of the primary mission objectives and continue in an extended mission. And that's not all... this hardy spacecraft, continues to operate well beyond our original expectations. It's the "little spacecraft that could".

Galileo spacecraft (JPL-12063AC)

Meanwhile, the spacecraft flew by an asteroid named Gaspra, the first time a spacecraft had been that close to an asteroid. Then it was back to earth for the final slingshot fling toward Jupiter. We were to pass by the earth at only 305 kilometers (190 miles) so we had to target perfectly. The final target before arriving at Jupiter proved to be the most interesting. We flew by the asteroid named Ida and discovered... that it has a moon, which was subsequently named Dactyl. This was a first.

- Galileo at Gaspra (P-40449)
- Earth-2 (PIA00232)
- Ida and Dactyl (P-44131, P-44297)

You're probably wondering how we got all these pictures back from the spacecraft, if the antenna isn't working. Well, they were recorded on the tape recorder and played back very slowly over the low gain antenna. This meanst that we receive the pictures many months after they are taken. In fact, it seems

So much for those two. Now, we'll see the really interesting satellites: Io and Europa.

Io is a tortured body. Jupiter's gravitational field causes tides on its surface of 100 meters, about 328 feet, in a solid surface. This is like rolling an orange around on a counter with your hand. The inside starts to get juicy. Finally, the rind breaks, and juice squirts out. That's what's happening to Io. The gravity of Jupiter pulls on the surface. The friction inside the satellite causes it to heat up and the inside melts. The surface cracks and volcanoes are formed. As a result, Io is the most active volcanic body in the solar system. Its surface is continually being covered over by sulfurous lava, so it has no impact craters. Its surface is only about a million years old. Its thin atmosphere is primarily sulfur dioxide. This would not be a fun place to live!

- Io pictures (PIA02526, PIA02502, PIA02308, PIA02506)

Finally, we have Europa. Its icy surface looks like a puzzle that has been broken apart and put back together in the wrong way. It's geologic history is very complicated. These "puzzle" pieces seem to float like icebergs on a sea. They are rotated, tilted, and sometimes look like a fluid came from the interior and covered them over in icy puddles. This causes scientists to ask if there is an ocean beneath the icy crust. Very possibly. The next logical question is whether some form of life exists in the ocean. We know from studies on earth that life can exist in extreme environments. Does Europa have the constituents to support life? For the past two years, the Galileo mission has concentrated on studying Europa to unlock the answers.

- Europa pictures (PIA00502, PIA01127)

Where do we go from here? NASA's solar system exploration program asks the following questions:

- How and when did life form on earth?
- Does life exist elsewhere in the solar system or in the universe?
- How did the solar system evolve over time?
- What can other planets teach us about earth?

To answer these questions, we need to continue to study the other planets. Jupiter and its moons are a key to understanding these questions.

The next mission planned to go to Jupiter will be the Europa Orbiter mission, sometime during this decade. After that, maybe a lander that could melt through the surface. Meanwhile, Galileo, the "little spacecraft that could", continues to orbit Jupiter and return interesting and exciting data of the planet and its moons.